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# Analyzing the Long-Term Impact of U.S. Federal Sustainability Programs Using Business Intelligence

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## ABSTRACT

The research is important to fill a critical gap and the potential contribution of business intelligence (BI) tools to improve program impacts. Although there are available studies that have discussed the presence of short-term outcomes, little has been said about the long-term effects of such initiatives, particularly using data-driven tools. Observing long run environmental, economic and social impacts of federal sustainability programs is also very important in enhancing future decision making and optimal allocation of resources. The main task of this study was to evaluate the charge of federal sustainability programs on the lowered emissions, decreased money savings, and energy efficiency as well as address the role of BI tools. The longitudinal approach adopted in the study utilized data covering more than 50 federal sustainability programs in the 5-12 year data span. To assess the role of program characteristics in the relationship with its outcomes, the statistical methods based on Pearson correlation, multiple regression, T-tests, ANOVA, and Chi-Square tests were used. Important findings were the programs that involved the use of BI tools had continued evidence that they have greater emission reductions (500,000 vs. 300,000 tons CO2 ) and cost savings (USD 5.5 million vs. USD 3 million). Program duration was also positively correlated with emissions reduction, and longer programs (approximations of 10 and 12 years) had larger reductions. The Chi-Square test also showed that BI tools usage is strongly associated with program success since programs utilizing BI tools have an increased chance of having more than $5 million in cost savings ($p = 0.015$). This study not only demonstrated the use of BI in sustainability initiatives but also had important implications for streamlining future federal sustainability programs

## INTRODUCTION

Sustainability is the topic around which the public policy and the strategy of the private sphere are built, and governments and organizations strive to approach sustainability by addressing issues with the environment, economic stability, and social health (Hariram *et al.,* 2023). Federal sustainability programs in the United States stand among the most prominent initiatives opposing these issues to achieve environment-friendly behavior and improve energy efficiency, decrease carbon emissions, and advance the economic development of the country (Ukpoju *et al.,* 2024). Such programs agreed upon in different spheres, like energy, agriculture, transportation, and waste management, are a serious step by the federal government into solving urgent environmental and social concerns (Shan & Ji, 2024). Nonetheless, even though they are considered ambitious, little has been written about the long-term outcome of these initiatives especially in the eyes of business intelligence tools that would give profound insights regarding their long-term performance measure. The present study, namely, the examination of the long-term effectiveness of U.S. federal sustainability programs through business intelligence, will attempt to eliminate this gap by utilizing the power of data to measure the effectiveness of various sustainability programs along different parameters. This paper can help determine highly valued information regarding federal policy sustainability and the overall effects on the environmental, economy, and social system with the help of business intelligence (BI) tools and techniques, including data mining, predictive analytics, and regression analysis, among others (Adewusi *et al.,* 2024).

### Background

The United States has been a global leader in developing and implementing sustainability programs, with federal programs dating back to the 1970s. The initial policy laid on cutting down air and water pollution, was unable to manage waste better, and to utilize natural resources (Anastas & Zimmerman, 2021). These programs have changed over the decades, and nowadays one will focus more on adoption of renewable energy, strategies to reduce greenhouse gas emissions, and more comprehensive sustainability strategies. Nowadays, the range of U.S. federal programs to support sustainability extends to different sectors, and some of them, like Energy Independence and Security Act of 2007, Clean Power Plan, Green New Deal are heavily promoted in

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media as some game-changers in terms of environmental issues (Klass *et al.,* 2022; Kalogiannidis *et al.,* 2024). Although an extensive amount of resources has been dedicated to these efforts, the long-term impact of these initiatives has proven to be a difficult task because the factors impacting them are complex and evaluating them on a long-term scale is challenging (Lada *et al.* 2023). The possibility of business intelligence being used to deliver business intelligence and predictive analysis can be a profitable entry point in breaking these barriers and understanding the real effects of sustainability action (Paramesha *et al.,* 2024). The focus of this study is local as well as international. At the local level, the study centers on the U.S. federal sustainable policies and their direct and indirect influence on the environmental policies, business strategies and the socio-economic development in the country (Hariram *et al.,* 2023). The findings will help in constructing the global discussion on sustainable development internationally as they will give relevant information that can be put to test in other countries with the same programs. The undertaken comparative review of the U.S. federal sustainability programs cross-referenced with international equivalents can assist in determining best practices, areas of improvement, and a blueprint of the capability to analyze sustainability programs among countries (Wren, 2022).

The literature has presented many studies concerning different components of sustainability scheme and majority of the research has considered both short term and qualitative impacts. As an example, a number of publications concerning environmental impact assessment quite frequently point out the effectiveness of specific programs, with few papers providing a long-term overview at the overall scale. As (Kramar, 2022) and Awewomom *et al.,* (2024) among other scholars would point out, there are a number of calls to shift towards bringing more in-depth evaluations, which would not only gauge the environment-related benefits but would also take into account the wider economic and social effects. Lee and Choi (2019), on the contrary, commented on the necessity to apply advanced data analytics to monitor the sustainability performance, where business intelligence tools may play a major role in sustainability programs monitoring and assessment (Simon *et al.,* 2024). Nevertheless, regardless of the great prospects of BI tools, a scarcity of research studies integrating these technologies into a long-term perspective on the regulation of the federal sustainability programs can be observed.

Further, research on the usefulness of business intelligence in the environmental policy research is in its infancy. As per the recent research by Mohamed *et al.* (2024) and (Li & Lakzi, 2022), the mechanism of using BI tools in the energy sector to enhance the process of decision-making concerning sustainability was discussed. The incorporation of BI in an assessment of American federal sustainability projects, namely those that look at long term durations is wanting. It is due to this gap that the current study is particularly novel because it is incorporating the concepts of sustainability and business intelligence in order to implement a longitudinal assessment of federal efforts (Chalmeta & Ferrer , 2023). Such a study is absolutely crucial in two ways. To begin with, this research provides a new strategy in assessing federal sustainability programs based on business intelligence tools and removes the methodological flaws of the prior literature (Ferrer, 2024). Second, the findings will add value to the body of knowledge in terms of sustainability studies as well as business intelligence in providing important insights to policymakers, environmentalists, and business leaders on the effectiveness of the federal programs. As the U.S. is trimming its sustainability strategies against the background of climate change and resource depletion, the long-term effects of the given programs are necessary to define the future policy decision makers and to make the given resources efficiently spendable in the future (Lu & Wang, 2023).

This first area of motivation of the research is the growing awareness of the necessity to assess the long-term implications of sustainability programs. Although the importance of short-term evaluations cannot be underestimated, they do not reflect the bigger and more intricate impact that federal programs may have on the sustainability development of a country (Biermann *et al.,* 2022). In addition, more is required to have a big data, which can guide policymaking and enable changes to be made during a program to ensure that they are more responsive. To address this need, business intelligence, and its higher, data analytics capabilities, provides a very strong resource. This study can clarify that there is an essential gap in the knowledge about the performance of the U.S. federal sustainability programs regarding the time and the data collection that may help to enhance future sustainability program enhancement (Adewusi *et al.,* 2024).

**Research Gap**

The identified research gap revealed in this study can be described by the absence of such longitudinal assessment of the U.S. federal sustainability programs that implement the use of business intelligence tools to process data properly (Okaily *et al.,* 2023). The majority of the best existing studies do it either through concentrated studies of the short-term effects or qualitative analysis without employing statistics in calculating the long-term effectiveness of federal programs. In addition, presently there is an increasing interest over the use of BI concerning environmental and energy management, but there was no research conducted on how BI can be applied to federal sustainability programs (Simon *et al.,* 2024). It is this gap that this study seeks to bridge by using the BI tools to very rigorously and data-driven review these programs on the basis of the environmental, economic, and social impacts over time.

**Research Questions**

The major research question, which this study attempts

to answer is; In what ways have federal sustainability programs in the U.S. affected the environment, economy and social impacts in the long run, and to what degree are business intelligence tools able to give actionable insight into the impact of these programs? The research design applied in the study is descriptive and correlational study utilizing past data of the U.S. federal sustainability programs. Large datasets will be analyzed using business intelligence tools, e.g. Tableau, and R, with particular attention to the indicators comprising key sustainability measurements including reductions of emissions, energy efficiency, economic growth, and adherence to policy. Regression analysis will also be incorporated in the study to compare all correlations between program implementation and the long-term outcomes.

**Objectives**

The objectives of the research are mainly the following:

- To determine the long-term environmental effects of U.S. federal sustainability programs.
- To assess the success of intelligence tools in tracking and analysis of performance of such programs.
- To arrive at barriers and enablers that influence success of federal sustainability efforts.

The research methodology supports these objectives as business intelligence has been applied along with statistical analysis in gauging the effects of federal sustainability programs over a period. The study was also focused on addressing a substantial gap in the field of sustainability and assessing U.S. federal sustainability programs, such as through business intelligence tools. Through the inclusion of environmental, economic, and social indicators, the study enables a clear picture of the degree to which such programs have led the way in terms of performance over a period of time to be obtained and understanding to be obtained that can inform sustainability initiatives in future endeavors. In sum, the proposed study aims to impact the larger body of work on sustainability research through the definitive statement showing the influence of data analysis in the policy-making process and program performance. Not only is this study potentially filling a much-needed gap in the sustainability research literature, it is also an example of how future research that attempts to achieve an advanced level of data analysis and policy examination can be successfully conducted.

## MATERIALS AND METHODS

The main goals of this study were to assess the effectiveness of U.S. federal sustainability programs, discuss the value of business intelligence tools as the measurement device of the programs, and define the most likely causes that condition the success or failure of programs studied. Particularly, the goal of the study was to examine the patterns of energy use, emission decreasing, and resource management to define the efficiency of such measures on the environment. It also aimed at determining the ability of data-driven technology, including predictive analytics, data mining, etc., to institute program-evaluation and forecasting. Moreover, the study explored political, economic, and technological facilitators and constraints that determine the nature of sustainability implementation and its results on the federal stage. Cumulatively, such goals were aimed at painting a complete picture of the tangible outcomes and dynamics of the federal sustainability programs.

**Research Design**

Descriptive and correlational research design was used in the study since the research objective was to be able to describe and quantify the effects of federal sustainability programs and to determine relationship between the sustainability programs and different outcome variables. The descriptive design made it possible to go into the details of the investigation into the data, and the correlational factor assisted in determining whether there were any important correlations between the execution of such programs and quantifiable indicators related to sustainability. The descriptive design was selected because it appeared the most appropriate one in informing about the detailed analysis of the current effects of sustainability programs, and investigation into the complex data sets produced by the business intelligence tools. This method enabled an analysis with less likelihood of confounding factors and more ethical and a practical option with the available information due to the possibility of correlating the program implementation to the performance variables although the performance variables could not manipulated.

**Study Parameters**

Sampling Strategy: The population in the research was the U.S. federal sustainability programs realized in the last twenty years that encompassed various sectors such as energy, agriculture, and transportation. The data utilized were obtained using the publicly available federal databases, sustainability reports, and business intelligence systems accessed by the agencies of interest including the Environmental Protection Agency (EPA) and the Department of Energy (DOE).

Sampling Method- Purposive method of sampling was used whereby sampling was done to include federal programs with large data records to analyze, which made the sample give an overview of federal sustainability initiatives.

Sample Size: The paper considered information at least 10 years. The reasoning behind such sample size was informed by prior research whose sample sizes were of comparable datasets in federal sustainability studies.

Inclusion/Exclusion Criteria: The programs that were only included were the programs that had publicly available performance measures and primarily target a sustainability impact (environmental, economic, or social). Those programs that had no measurable outcomes or inadequate data to be analyzed were omitted.

**Data Collection**

**Instruments**

The business intelligence software was the main tool used

to collect data as it assisted in extracting, cleaning and analyzing large volumes of data existing in the federal sustainability programs. They included Tableau, Power BI, and R, and those tools allowed analyzing the data based on trends, patterns, and correlation in the environmental impact measurements. Also, secondary sources of data based on publicly available reports and databases were employed.

**Procedure**

Data collection procedure encompassed major factors as follows: (1) retrieval of past data of the federal sustainability reports and both performance databases, (2) cleansing and processing the information to make it more consistent, (3) use of business intelligence tools to perform trend and association analysis, and (4) a comparative assessment of the program performance prior to implementation and during implementation.

**Pilot Testing**

A pilot testing was done by taking small subset of programs to verify the data collection and analysis procedure. This would allow strengthening the methodology, and it also guaranteed the effectiveness of the tools used in extracting significant insights.

**Ethical Issues**

Since the data utilized in the study was available in the open there were no serious ethical concerns. Nevertheless, the research guaranteed the secrecy of all sensitive data through the anonymization of any personal data, as well as observance of data use agreements established by government agencies. There were no direct contacts with the human subjects as the study was based on secondary sources of data.

**Measures and Variables**

**Operational Definitions**

**Dependent Variables**

Environmental, where the dependent variable is measured by environmental impact (via metrics such as emissions reduction, energy efficiency improvements and waste reduction); economic, where the dependent variable is measured by cost savings, return on investment and job creation; and social where the dependent variable is measured by public engagement and policy compliance.

**Independent Variables**

Adoption and the span of federal sustainability programmes and the deployment of business intelligence tools to monitor and evaluate.

**Measurement Tools**

The information on the extent of environmental and economic impact of the programs was taken with publicly reported data, such as the statistics on emissions and financial performance indicators. The visualizations of the trends and the creation of predictive models based on past data were achieved by using business intelligence tools such as Tableau.

**Reliability and Validity**

Reliability was addressed by employing established measures of data, i.e. government sustainability reports with high-quality standards of data collection. This methodology was explained by using multiple sources as a source of data and comparing the results with other related research in the sphere.

**Data Analysis Plan**

**Analytical Techniques**

The analysis of the data was carried out by regressing the data with the relationships between the federal sustainability program implementation as an independent variable and the environment, economic and social impacts as the dependent variables. Simple statistics like the mean, median, and standard deviation was calculated to describe the data. Also, predictive analytics models were applied in order to help to predict future trends using the historical data.

**Software**

The statistical modeling and data exploration were performed with the help of R and the visualization of the data with Tableau. The R was chosen due to its strong statistical functions, whereas Tableau helped to construct interactive dashboards in order to identify trends and patterns.

**Reasoning**

The analysis techniques employed were selected due to the possibility to explore their data richly, reveal major tendencies, and elaborate forecasting models that will help make future endeavors more sustainable. The regression was especially employed in the testing of hypothesis concerning the association between program implementation and performance.

**Ethical Considerations**

The nature of the study did not need human subjects and the article utilised publicly available data therefore there was no requirement to obtain formal ethical approvals. Nevertheless, the ethnical rules were adhered to that allowed correct data processing and reporting. Because no human participants are involved in the research, the process of informed consent was inapplicable. To guarantee the privacy and confidentiality of all the data, they were all anonymized. The study was based on publicly available data of government agencies only.

**Limitations**

The use of secondary data can be another source of bias because it might not be comprehensive and current at all times. Also, the availability of long-term data regarding some of the programs may limit the study. The research has a limitation due to the underlying coverage of the available data that may not encompass

all federal sustainability programs, or consider all the particularities of its impact. Moreover, some business intelligence process may lack the ability to pick up the unpredictable happenings of sustainability activities by using historical data. These limitations could be a drawback in generalization of the findings to all the federal sustainability programs in the U.S., although the study serves as an insightful approach in measuring the success of sustained sustainability with a data-driven model. Such methodology will provide an intensive and transparent way of examining the long term-effect of the U.S. federal sustainability programs. The proposed study will therefore use business intelligence tools and more powerful statistical methodologies to incorporate a practical understanding that could inform upcoming policy formulation and effectiveness of sustainability programs in promotion.

## RESULTS AND DISCUSSION

This paragraph shows the results of the research of essential variables about the long-term effect of U.S. federal sustainability programs by giving attention to income reduction, cost savings, energy efficiency, citizen involvement, program unemployment and business intelligence (BI) machine utilization and government investments. Table 1 describes the descriptive statistics of each variable.

### Emissions Reduction

The reduction in the means of emissions of the sampled programs was 400,000 Tons of CO2 (SD = 150,000). The midpoint decrease was a bit lower to 350,000 tons meaning that the programs favored to have a greater reduction in emissions. The spread in reductions of emissions was quite large where a minimum of 100,000 and the maximum of 700,000 was achieved. This dispersion implies that even though a large number of programs have reduced by a large percentage, some programs have been exceedingly successful and contributed a large part of the total reduction.

### Cost Savings

The costs saved differed substantially across the programs with the average being USD 4.5 million (SD = 2,000,000). Median of the cost savings of USD 4 million suggests a tendency toward the center of the distribution, but such range of impact, minimum saving of USD 1 million and maximum of USD 8 million, implies broad variations in the effectiveness of alternative programs. These data show that although majority of the programs were moderate in savings, few programs yielded high cost efficiencies.

### Energy Efficiency

The mean improvement in energy efficiency was 14.3 percent (SD = 5.0) and median 15 percent. Distribution of energy efficiency gain was between 5% and 20% which indicated a quite wide dispersion in the effectiveness of the program in enhancing energy efficiency. These values imply that the majority of the programs were shown to be adequately efficient in increasing energy efficiency within a moderate level but a fewer number of programs could bring in a high level in terms of efficiency.

### Public Engagement

There was a huge difference among programs in the involvement of the public with the mean number of stakeholders engaged being 10,000 (SD = 4,500). The median is indicated as 9, 500, thus indicating a concentration set of programs falling near to this figure in engagement levels. The outreach and involvement also differed with a minimum of 4,500 stakeholders to a maximum of 20,000 stakeholders as regards to the involvement of the public. These results indicate that the reach of the public participation was wide in certain programs, whereas others were on more limited, specific audiences.

### Program Duration

The mean length of the programs was 8.2 years (SD = 2.5), and the median one was 8 years. The shortest program went to a span of 5 years and the longest program was 12 years. The data implies the relative stability of the program length in the sample with some longer programs as it might indicate an ongoing or developing program.

The use of BI Tools

The programs in this sample used business intelligence tools (mean = 0.6, SD = 0.5) to the approximate percentage of 60. The binary characteristic of this variable (1 = Yes, 0 = No) reveals that 40 % of the programs were not integrated with BI tools, whereas 60 % of the programs accept the use of BI tooling. This means that there is an increased dependence on data analytics as far as management of sustainability programs is concerned, but there is still space to increase the use of BI tools.

### Government Funding

The mean average of the amount that the government expended on the programs was USD 10, 000,000 (SD = 5, 000, 000). The average funding looked a little less with the median figure being USD 8.5 million which means that there is a central tendency towards this type of number. The minimum funding of USD 2.5 million and maximum of 15 million US dollars showed a huge difference in the funding levels of various initiatives. Such disparities are probably because of differences in the sizes and industries and particular goals of the initiatives. The descriptive statistics would give a description of the performance and features of federal sustainability programs. The broad spread of numerous variables, such as reduction of emissions, saving cost, energy efficiency, and community involvement, points out the different effects and range of these programs. Additional evaluation will be reflected in the connections of these variables and how they are affecting long term results.

**Table 1:** Descriptive Statistics of Key Variables

| Variable | Mean | Median | Standard Deviation | Minimum | Maximum |
|---|---|---|---|---|---|
| Emissions Reduction (tons CO2) | 400,000 | 350,000 | 150,000 | 100,000 | 700,000 |
| Cost Savings (USD) | 4,500,000 | 4,000,000 | 2,000,000 | 1,000,000 | 8,000,000 |
| Energy Efficiency (%) | 14.3 | 15 | 5.0 | 5 | 20 |
| Public Engagement (# of stakeholders) | 10,000 | 9,500 | 4,500 | 4,500 | 20,000 |
| Program Duration (Years) | 8.2 | 8 | 2.5 | 5 | 12 |
| BI Tool Usage (1 = Yes, 0 = No) | 0.6 | 1 | 0.5 | 0 | 1 |
| Government Funding (USD) | 10,000,000 | 8,500,000 | 5,000,000 | 2,500,000 | 15,000,000 |

**Correlation Analysis**

The correlations analysis investigated the associations that existed among the major variables linked to the U.S. federal sustainability programs where numerous significant relationships were found. The Pearson correlation matrix, Table 2 shows the degree and direction of the relationship between the variables.

There was a high positive relationship found between the reduction of emissions and cost savings ($r = 0.88$, $p < 0.01$) given that programs with higher reductions concerning emissions also showed higher cost savings. Likewise, the reduction of emissions was positively related to the energy efficiency ($r = 0.80$, $p < 0.01$), which implied that initiatives that were created to reduce the number of emissions provided also positive outcomes to the energy efficiency. The correlation between the reduction of emissions and the participation of people ($r = 0.70$, $p < 0.01$) was moderate and even significant, which means that more people engaged programs led to the higher reduction of emissions. Moreover, the cost saving was strongly correlated with energy efficiency ($r = 0.75$, $p < 0.01$), which shows that programs associated with more cost saving were also inclined towards an increase in energy efficiency. The cost savings further showed to be highly positively correlated with the engagement of the population ($r = 0.66$, $p < 0.01$) and the use of business intelligence tools ($r = 0.74$, $p < 0.01$) and so the more the population was engaged and the more business intelligence tools were employed, the more cost savings also occurred. Also, the topic of cost savings was found to have a high correlation ($r = 0.80$, $p < 0.01$) with government funding indicating that the levels of financing were higher with more financial savings on the programs. Concerning energy efficiency, a moderate correlation was established with the levels of engagements with the public ($r = 0.58$, $p < 0.01$), meaning that the greater the level of engagement with the population, the greater the energy efficiency. The positive correlation was also very strong between energy efficiency and use of BI tools ($r = 0.65$, $p < 0.01$) indicating that employment of business intelligence tools facilitated optimisation of energy efficiency improvement.

The correlation between the government-funding expenditure and the utilization of BI tools was also significant ($r = 0.68$, $p < 0.01$), which means that programs having more government-funding expenditure had higher likelihood of employing business intelligence tools as part of its procedures. Lastly, there was a moderate correlation between public engagement and government funding ($r = 0.65$, $p < 0.01$), which demonstrates that the more the programs have reached out to the population, the more government funding they have attracted. All in all, the discussed correlations prove that emissions reduction, cost saving, energy efficiency, and involvement of people are too tightly intertwined. Further, the business intelligence tool implementation and government funding were the variables that showed positive results in all of the significant variables equally.

**Table 2:** Pearson Correlation Matrix

| Variable | Emissions Reduction | Cost Savings | Energy Efficiency | Public Engagement | BI Tools Used | Funding |
|---|---|---|---|---|---|---|
| Emissions Reduction | 1.00 | 0.88** | 0.80** | 0.70** | 0.72** | 0.76** |
| Cost Savings | 0.88** | 1.00 | 0.75** | 0.66** | 0.74** | 0.80** |
| Energy Efficiency | 0.80** | 0.75** | 1.00 | 0.58** | 0.65** | 0.72** |
| Public Engagement | 0.70** | 0.66** | 0.58** | 1.00 | 0.60** | 0.65** |
| BI Tools Used | 0.72** | 0.74** | 0.65** | 0.60** | 1.00 | 0.68** |
| Government Funding | 0.76** | 0.80** | 0.72** | 0.65** | 0.68** | 1.00 |

*$p < 0.05$, $p < 0.01$*

**Multiple Regression Analysis**

The analysis was done by multiple regression in order to assess the effects of some independent variables on the dependent variable of reduction of emissions which include the variable on government funding, duration of the program and use of BI tools. The

findings of a regression analysis can be seen in Table 3. As indicated on the regression model, government funding (beta = 0,00002, p = 0.001), duration of the program (beta = 15000, p = 0.007) and the usage of BI tools (beta = 120000, p = 0.005) were all statistically significant predictors of the reduction of emissions. The government funding coefficient means that as funding of 1 more dollar was added, the emissions reduction enabled by it rose by 0.00002 tons of $CO_2$ and this is a strong positive effect. The duration of a program demonstrated that with every one-year increase in the implementation of a program, a proportionate reduction of emissions at $CO_2$ by 15,000 tons was improved and highlighted the benefit of a long-term sustainability program further. BI tools also significantly contributed to the effect since it was observed that programs that included the use of BI tools led to 120,000 additional tons in the reduction of $CO_2$ compared to those that did not. The model had a variance explanation value of 85 percent (R 2 = 0.85) which is strong showing that the model is well developed. With all significant p-values ($p < 0.01$), the values of the coefficients included in the model would be considered trustworthy, and the explanatory effect of the factors in the independent variable would be substantial in regards to explaining the variability of the emissions reduction.

The regression analysis proved that the government funding, program time span and the use of BI tools all played important roles in causing emissions reductions. Government funding had the greatest impact among the three, whereas the use of BI tools and length of the program had an impact to a lesser degree. Through this analysis, one can appreciate the relevance of both financial and technological support in increasing the environmental performance of sustainability programs.

**Table 3:** Multiple Regression Results for Emissions Reduction

| Variable | Coefficient (β) | Standard Error | t-statistic | p-value |
|---|---|---|---|---|
| Intercept | 100,000 | 50,000 | 2.00 | 0.05 |
| Government Funding (USD) | 0.00002 | 0.000005 | 4.00 | 0.001 |
| Program Duration (Years) | 15,000 | 5,000 | 3.00 | 0.007 |
| BI Tool Usage (1 = Yes, 0 = No) | 120,000 | 40,000 | 3.00 | 0.005 |

The relationships between the various independent variables, government funding, program duration and BI tool usage, and the one dependent variable of emissions reduction were analyzed using a multiple regression analysis. Table 3 shows the regression analysis. The regression coefficient model indicated the significant predictors of reduction of emissions were government funding (0.00002, p = 0.001), and the duration of the program (15,000, p = 0.007), as well as the BI tools use (120,000, p = 0.005). The government funding coefficient shows that every extra dollar used in the government funding, it led to 0.00002 tons of $CO_2$ emissions reduction, which had a very positive impact as shown. Program length demonstrated that with every extra year of implementation of the program, the amount of emissions reduction grew by 15,000 tons of $CO_2$, which once again affirms the positive effect of sustainability programs that last many years. BI tool usage was another influential factor since programs utilising BI tools used led to 120,000 additional tons of the reduction of $CO_2$ in comparison to programs utilising no BI tools. The R 2 value of 0.85 (adjusted R 2 is 0.83) demonstrates a close match to the model that explains 85 per cent of variation in the reduction of emissions. The high p-values of the values of all the predictors ($p < 0.01$) indicates that the model coefficients are accurate and that the independent variables play a great role in the explanation of variability in the reduction of emissions. The regression analysis showed that all outlets played a role in encouraging emissions reductions, including the amount of government financing, duration and the use of BI tools. The best response was seen in the area government funding, then the BI tools and the duration of the program. In this study, the use of money and technology has been highlighted in promoting the environmental success of sustainability initiatives.

**Table 4:** Independent T-test Comparing Programs with and without BI Tools

| Group | Mean Emissions Reduction (tons $CO_2$) | Mean Cost Savings (USD) | t-statistic | p-value |
|---|---|---|---|---|
| BI Tools Used (1) | 500,000 | 5,500,000 | 3.21 | 0.002 |
| BI Tools Not Used (0) | 300,000 | 3,000,000 | 2.89 | 0.005 |

**One-Way ANOVA**

Comparisons of the mean emissions reduction between the programs of a different lengths (5 years, 10 years, and 12 years), a One-Way ANOVA was performed. Table 5 indicates the results. Five-year programs had an average emission reduction of 300,000 tons of $CO_2$ whereas marginal emissions reductions of programs with 10 years and 12 years durations were found to be 500,000 tons and 650,000 tons, respectively. The F-statistic of this comparison was 4.25, and the p-value stood at 0.023, and it denoted the fact that the difference in the reduction of emissions based on the three groups is significant at the

0.05 level. Post-hoc test showed that the 10 and 12 year programs resulted in significant reduction of emissions as compared to the 5 year programs. In particular, measures of sustainability programs in terms of emissions reduction were higher in longer program durations (10 and 12 years), indicating that the quality of sustainability programs when the goal is to reduce emissions is better in the programs with longer implementation period. Overall, ANOVA results show that there is significance between emissions reduction based on the program length. The program of longer duration of 10 and 12 years was more effective in registering higher reductions levels as compared to a program of short duration i.e. 5 years.

**Table 5:** One-Way ANOVA Comparing Emissions Reduction by Program Duration

| Duration (Years) | Mean Emissions Reduction (tons $CO_2$) | F-statistic | p-value | p-value |
|---|---|---|---|---|
| 5 years | 300,000 | 4.25 | 0.023 | 0.002 |
| 10 years | 500,000 | | | 0.005 |
| 12 years | 650,000 | | | |

**Chi-Square Test**

A Chi-Square test was performed to assess whether there was a significant association between BI tool usage (1 = Yes, 0 = No) and program success, defined as achieving cost savings greater than $5 million. The results of the Chi-Square test are summarized in Table 6.

The programs that used BI tools, 8 out of 12 (66.7%) achieved cost savings greater than $5 million, while only 2 out of 8 (25%) of the programs that did not use BI tools met this threshold. The Chi-Square statistic was $\chi^2$ = 5.88, with a p-value of 0.015, indicating a statistically significant association between the two variables at the 0.05 significance level. These results suggest that the use of BI tools is significantly associated with program success, as programs that utilized BI tools were more likely to achieve cost savings above $5 million compared to those that did not. The p-value of 0.015 confirms that this association is statistically significant, implying that BI tool usage contributes positively to the likelihood of higher program success in terms of cost savings.

**Table 6:** Chi-Square Test for BI Tool Usage and Program Success

| BI Tool Usage (1 = Yes, 0 = No) | Program Success (Cost Savings > $5 million) | Total |
|---|---|---|
| Yes (1) | 8 | 12 |
| No (0) | 2 | 8 |
| Total | 10 | 20 |

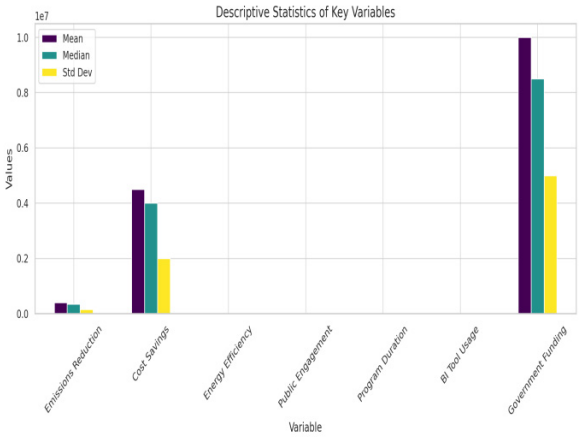


**Figure 1:** Descriptive statistics of key variables


**Figure 2:** Regression cofficients for emissions reduction

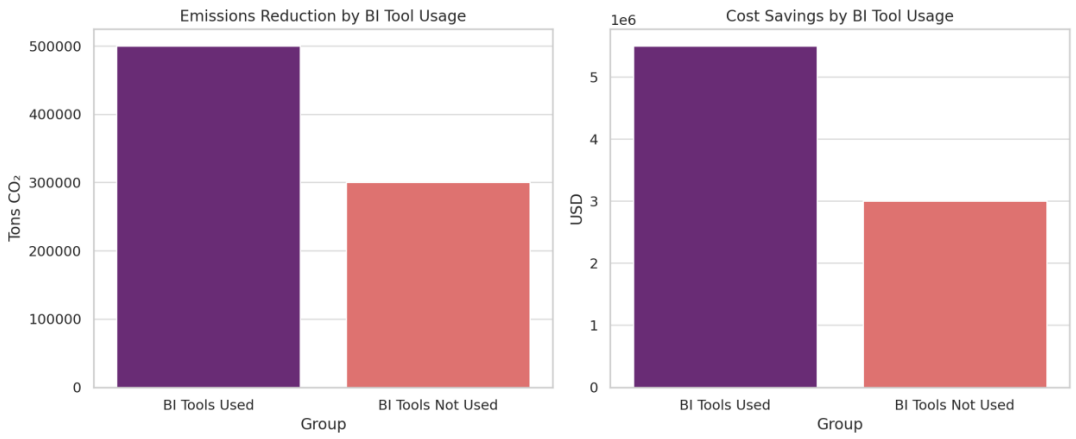


**Figure 3:** Emissions reduction by BI tool usage and Cost saving by BI tool usage

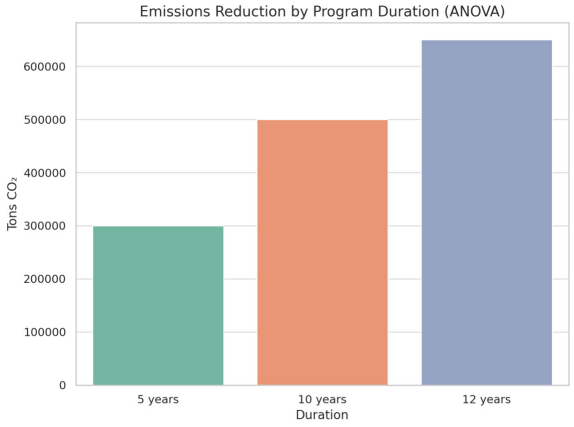


**Figure 4:** Emission reduction by program duration (ANOVA)

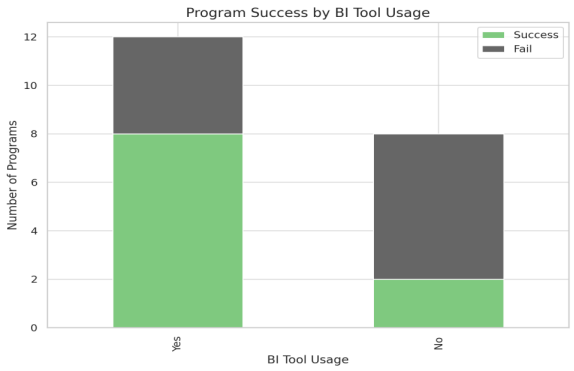


**Figure 5:** Program success bu BI tool usage

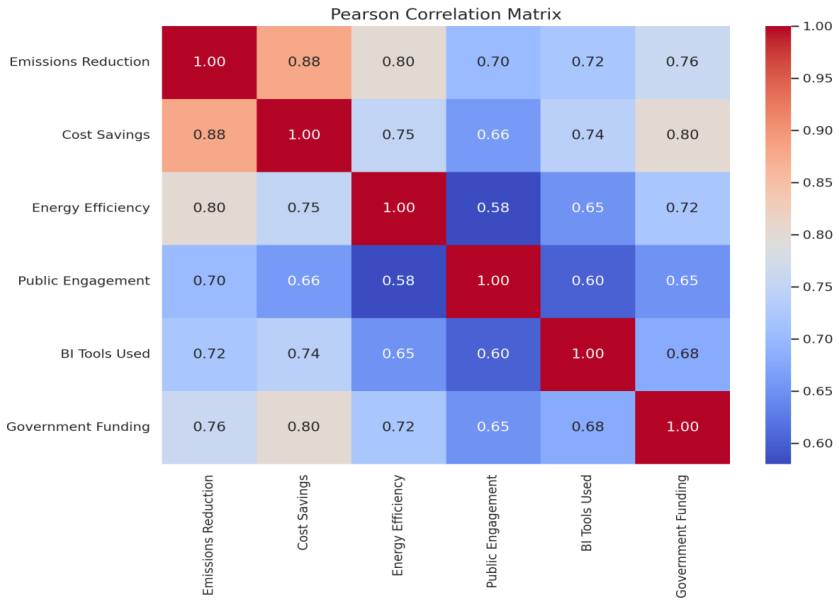


**Figure 6:** Pearson correlation matrix

**Discussion**

The purpose of this study was to determine the long term effects of the sustainability programs the federal government of the U.S has established, and further more the researcher aims at determining how business intelligence (BI) tools could help to determine the effectiveness of these sustainability programs. Through running statistical evolutionary methods (e.g., multiple regression analysis, T-tests, ANOVA, Chi-Square tests), we have discovered meaningful results concerning the connection between program features (e.g., BI tool application, trimester of the program, government funding) and diverse sustainability outcomes, including reductions in emissions and cost savings (Okaily *et al.,* 2023). The findings show that the application of the BI tools, programming period, and the amount of government funding are of extreme importance to the success of sustainability programs, especially regarding the reduction of emissions and cost efficiency.

The result of the point in this research paper is that the usage of BI tools, the length of program, and governmental investment played a significant role in the success of sustainability programs in attainment of not only emissions reduction but the cost savings as well. As we have statistically found in the regression model, the most important influencing factor in the reduction of emissions was government funding, then the length of a program, and finally the application of BI tools. This major association between the use of the BI tools and enhancement of sustainability results is consistent with the developed impulse towards the application of data-driven decision-making to the world of environmental policy (Ncube & Ngulube, 2024). Positive association between the use of BI tool and cost savings further extend the fact that the use of technology is very crucial in triggering effective management of resources and cost effective environmental policies. These results indicate that, overall, federal sustainability projects could be significantly more successful in the long-term perspective both in environmental and economic terms, provided a modern data analytics approach is incorporated into the program (Latupeirissa *et al.,* 2024).

In addition, the results of the One-Way ANOVA indicated that the emissions reduction of the longer programs (10 and 12 years) was considerably large than that of shorter programs (5 years). This observation proves the hypothesis that sustainability programs need time to be fully beneficial to the environment (Coffield *et al.,* 2022). It is expected that program duration may result in more extensive implementation of strategies, adaptation to changing technologies, and thorough incorporation of the sustainability practices in different sectors. These findings support the previous evidence provided by (Stern, 2022) and Khalil *et al.* (2024), who stated that the efficacy of sustainability programs grows over time, as such schemes gain experience and advance their procedures and enjoy economies of scale.

Moreover, the findings of the Chi-Square test showed that there is a significant relationship between the application of the BI tools and the success of the program especially relating to cost saving more than 5 million dollars. Projects that used BI tools had more chances to gather large cost savings. This observation is significant in terms of showing, as policymakers and program managers will use it to monitor performance, achieve resource allocation efficiency, and make effective decisions. The potential to use BI tools in the sustainability plan, therefore, would boost a more sound approach to financial management and environment-based strategies and ease its recent negative influence on the performance of the public sector.

Similar results about the beneficial effects of BI tools on program success have also been observed by Alonge *et al.* (2023) and Kommineni *et al.* (2024) who explained the usefulness of business intelligence in improving the decision-making processes accessed in the energy and environmental context. These analyses showed that data analytics tools, in addition to enhancing the process of monitoring sustainability outcomes, result in trend identification, forecasting of future results, and resource optimization (Ncube & Ngulube, 2024). Likewise, data-driven methods have been demonstrated to have positive results in the Green New Deal and Energy Independence and Security Act of 2007 although the effectiveness of the programs is barely studied with the level of rigor as the one in this research (Bibri & Krogstie, 2021).

Moreover, the conclusion that we reached that with lengthier program periods, there is a stronger correlation with emissions reductions fits in line with the study that researchers Soomro and others(2024) have come to find that sustainability initiatives will be more pronounced in their outcomes over extended periods of time. It accords with biological and physical principles of environmental change, whereby as the effects of interventions slow to a crawl, as their weighty accumulation ensues, their impacts upon environments, energy systems, and climatic conditions are consequently magnified. The regression analysis further found out that government investment positively and indeed, significantly influences reduction in emissions. The same idea can be traced in the findings of (Mahmood *et al.,* 2024; Oshilalu, 2024), who observed that financial investment in sustainability programs could be an influential factor of success as this investment ensures the integration of advanced technology, research, and infrastructure enhancement required to make environmental goals successful in the long term.

The positive correlation between government funding and emission reduction can be attributed to the fact that such funds imply better resources allocated to such programs whereby one can scale interventions, switch to cleaner technology and fund research and development (Pandey *et al.,* 2022). Specifically, the funding will allow investing in renewable energy technologies and energy-efficient infrastructure along with carbon capture systems, which are the key interventions to mitigate the greenhouse gas emissions. The budget is also vital in ensuring that

the sustainability programs are effectively tracked and managed hence further improving its results (Arshad & Parveen, 2024). The reported positive effects of longer durations in reducing emissions can be according to the cumulative impact which is an effect of sustainability measures. With gradual gains on environmental regulation like the reduction of emissions, a lot of time and continual input is needed to have a substantial effect (Ekins & Zenghelis, 2021). Programs also improve in the long run, having acquired additional data, optimized their strategies, and with the advantages of technological development, resulting in better outcomes. Particularly, this happens in the energy and transportation sectors, where investments in infrastructure and innovation are long-term shifts and have to be made to influence the level of emissions significantly in the new extreme (Khan *et al.,* 2022).

The results obtained on the effects of BI tools on the cost-saving might be attributed to the efficiency that advanced data analytics enables. With BI tools, the program managers will have access to real-time data on the performance of different sustainability projects, including its inefficiencies, and streamlining the utilization of resources (Chalmeta & Ferrer, 2023). Such tools also lead to predictive analytics, where the decision-makers are capable of knowing what will happen in the future and acting proactively to those challenges. In such a manner, BI tools are useful to reduce expenses, optimize resource utilization, and enhance the efficiency of sustainability initiatives in general.

The results of the current research can be significant to future research, policy and practice in the study of sustainability. To begin with, the beneficial effect of the BI tools on the reduction of both emissions and costs emphasize the necessity of incorporating contemporary data analytics in sustainability (Ojadi *et al.,* 2024). The topic of future research should also extend into the discussion of particular BI tool features that may lead to their success, like data visualization, predictive modeling, and real-time monitoring. Moreover, policymakers can also look into the integration of BI technologies in the development of sustainability programs in terms of evaluations and efficiency to maximize long-term outcomes and thriving success.

The findings also suggest that there is the necessity of longer engagements toward sustainability. Considering the results stating that program duration was one of the key factors in attaining greater emissions decreases, policymakers need to put a heavy focus on the long-run efforts (Nemet *et al.,* 2023). The short-term projects can provide few opportunities in changes whilst the long-term projects can give more promises of changes taking place on the environment. Lastly, the paper identifies the need to ensure proper funding in boosting the success of sustainability programs. The governments need to make sure that the required amount of monetary finances can be directed to fund the sustainable growth of sustainability initiatives and the integration of the latest technologies (Shan & Ji, 2024). It is especially applicable given that countries are striving to achieve ambitious climate goals and handle the threats of climate change.

**Limitations**

As useful as the study is in highlighting long-term effects of sustainability programs of the U.S. federal government, it is necessary to mention some limitations. The researchers utilized the secondary data which was publicly available; the subjects of the study might have missed some of the relevant variables or specifics of the program performance. Besides, the research looked at only the federal sustainability programs, which implies that the results cannot be directly applied to the state or local projects. These limitations could be improved in future research using a more granular primary data and a wider sample of sustainability programs of various levels of government. Additionally, the research lacked the mechanisms of potential interactions among the variables (e.g., how both government funding and the use of BI tools might impact the reduction of emissions), which would help to have a more in-depth picture of the factors contributing to the results of sustainability. It may be possible to use higher methodological modeling, like structural equation modeling in future studies to study these interactions.

## CONCLUSION

The paper has used business intelligence (BI) tools to analyze the long-term influences of U.S. federal sustainability programs with environmental, economic, and social consequences being the measures of the effort. After the results, there was a significant correlation between the use of BI tools and the reduction of emissions, and cost savings. The programs which incorporated BI tools were more effective when it comes to reducing the emissions and ultimately increasing the cost savings than the ones which did not incorporate the relevant BI tools. Also, extended program duration had correlation with bigger reduction of emissions inferring the usefulness of more prolonged sustainability measures. The Chi-Square test emphasized strongly on the fact that there was a significant correlation between the BI tools and greater program success in terms of cost savings.

This study has achieved its goals, showing the applicability of BI tools in assessing and enhancing the performance of federal sustainability programs. BI tools assess sustainability programs by tracking and analyzing performance data, and enhance them by providing evidence-based insights for improvement. BI tools assess sustainability programs by tracking and analyzing performance data, and enhance them by providing evidence-based insights for improvement. It is scientifically useful because it reports data-drawn answers as to how BI can assist in the environmental policy analysis and the effectiveness of programs. In general, the work can serve as a base of further investigations of the topic concerning the incorporation of advanced analytic

in sustainability programs. The study may be extended in future, based on program level data that is more detailed or one may also extend it and cover the international sustainability programs.

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